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Calibration of a Sargent Steam Meter

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CALIBRATION OF A SARGENT STEAM METER

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED CALIBRATION OF A SARGENT STEAM METER

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

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L. P. Breckenridge.

HEAD OF DEPARTMENT OF Mechanical Engineering

Contents.

Calibration of a Sargent Steam Meter.

I Preliminary Remarks

Historical

The usual way of finding the water rate of an engine, or the evaporative performance of a boiler, is to either weigh the the water fed to the boiler or to condense and weigh the exhaust steam from the engine. Since this method entails considerable expense and trouble the demand has risen for an instrument that would record the amount of steam flowing through a pipe in a given time, and yet at the same time be reliable, cheap, and simple of operation. In order to meet this demand several steam meters have been designed and have been used with varying degrees of success. Owing to the varying conditions to be met with in steam practice, the problem has been a rather intricate one. The meters meeting with the most success so far are the Gehre meter, the Bayntun meter, and the C. E. Sargent meter. The first two mentioned are of foreign make, while the last one is an American meter, made by the C. E. Sargent Steam Meter Co, at Chicago Ill.

The Gehre meter is based on the fact that steam

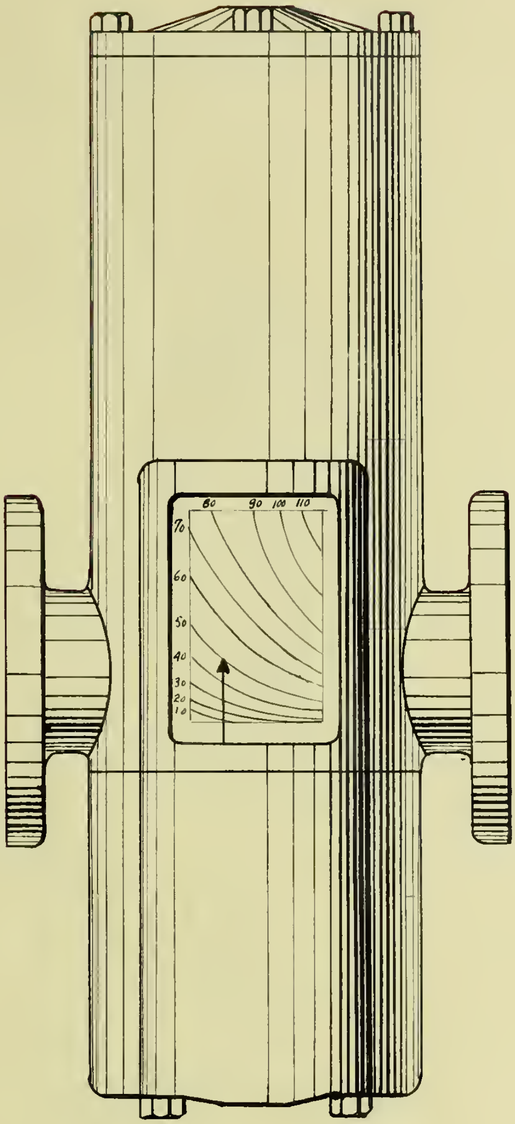
in flowing through an orifice produces a difference in pressure on the two sides of the orifice, which is proportional to the amount of steam flowing through. This difference in pressure is measured by inserting a plug in the orifice, leaving an annular opening between the edges of the orifice and the outside of the plug. The latter is fastened to a movable rod and works against a spring. To take care of the varying steam pressure a piston is fitted into the meter casing, and is also fastened to a rod and spring. A suitable recording mechanism registers the combined movement of these two so that the ordinates corresponding to the flow at any moment are recorded upon a moving sheet of paper. The whole theory of the meter is based upon Zeuner's formula :–

$G = \frac{[kF(P_1 - P_2)P_2]}{P_1V_1}$. In which G = wt. of steam flowing per second, F = area of the orifice in sq. inches P_1 = initial, and P_2 = final pressures, V_1 = specific volume at initial pressure, and k = a constant.

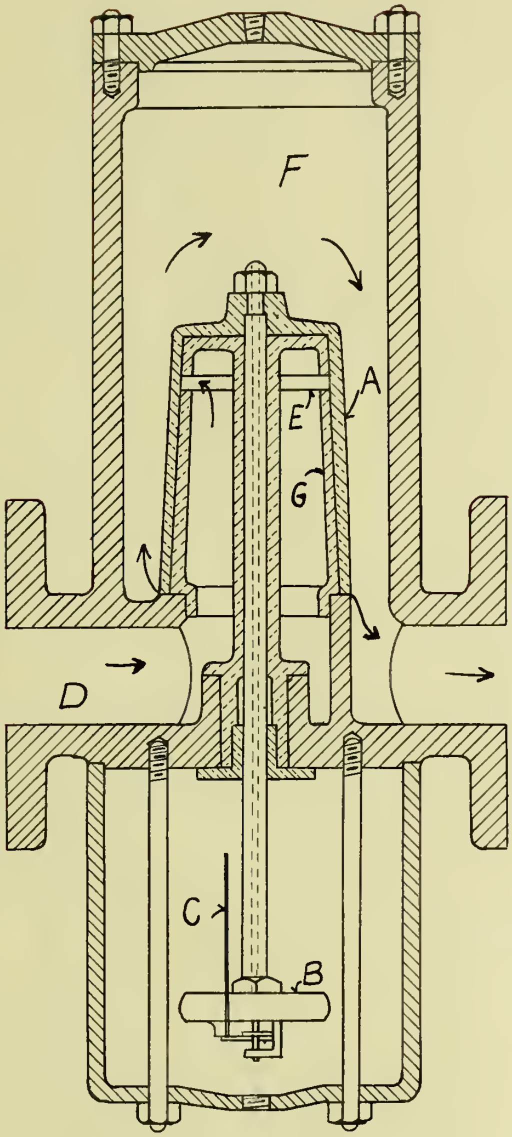
The Bayntun meter works on substantially the same principle as the Sargent meter discussed below.

Description of Sargent Steam Meter

A sketch of the Sargent meter is shown on page 5. Its operation depends upon the following principles: Assuming a constant density the weight of steam flowing through a given opening in a given time will depend upon the area of opening and the difference in pressure on the two sides, or to state it a little differently, with a given difference in pressure the area of an automatically adjusted opening will depend on the amount of steam flowing through. Referring to the sketch it can be seen that the meter consists of a casing containing a valve A, to the hollow stem of which is attached a Bourdon spring B, carrying a needle C. The stem is hollow in order to transmit the pressure in the upper part of the casing to the spring. Steam entering the opening D, passes up into the hollow cone shaped part G, on which the valve is seated, and which has an anular opening E. The steam pressure immediately lifts the valve from its seat and steam flows out of the opening at E, down between the valve and its seat, and out at the bottom as indicated by the arrows, into the chamber F, which discharges into the steam main.



100 H.P. SARGENT STEAM METER.



Cross Section of
Sargent Steam Meter

Let P_1 = pressure in conical chamber G, P_2 = pressure in chamber F, a_1 = area of top of valve, which is also essentially the area of the under side projected upon a plane perpendicular to the valve stem, a_2 = area of the valve stem, and W = weight of the moving parts. It may now be seen that for equilibrium,

$P_1(a_1 - a_2) = P_2 \cdot a_1 - W$, or $P_2 = P_1 \frac{(a_1 - a_2)}{a_1} + W$.

Since in a given meter, a_1, a_2, and W are fixed it follows that there will always be a fixed relation between P_1 and P_2, or in other words, P_2 will be a fixed percentage of P_1. In the meter under discussion P_2 is about 98% of P_1. This determines the difference in pressure spoken of before, and hence the area of valve opening will adjust itself to the amount of steam flowing through. Since the diameter of the valve is constant the area of opening will depend upon the lift of the valve. Therefore the lift will vary directly as the amount of steam passing.

With the above assumption, namely that that the density is constant, P_1 must necessarily be constant. If P_1 is increased the difference in pressure, $P_1 - P_2$ would increase and at the same time the density of the steam at the pressure in the opening would increase. Both the in-

creased difference in pressure, and the increased density will cause more steam to flow through a given opening, or if we assume the flow constant, it may be seen that a smaller opening will be sufficient to permit the passage. Therefore the valve lift at this pressure will be less than before, with the same weight of steam flowing through. Since the weight of steam is effected by both lift and pressure, it may be easily understood that it will not be sufficent to record only the valve lift as in the case when P_1 was constant, but that the recording apparatus must be arranged to take care of both. In the meter under consideration this is done as follows:- As the needle mechanism is attached to the valve stem the lift of the valve will cause the needle to move in a vertical direction, while the pressure transmitted to the Bourdon spring through the hollow stem will cause the needle to move in a horizontal direction. As proved above, with a given quantity of steam passing through, as the pressure increases the valve lift decreases and at the same time the needle moves across the dial. Hence, due to these two motions combined, the needle will follow a fixed curve on the dial as the pressure varies between the limits of the meter. This curve may be called a

constant weight curve. Instead of reading in weight per hour the meter may be calibrated to read direct in horse power, since the horse-power is defined as 30 pounds of water per hour evaporated from feed water at 100°F and 70 pounds pounds boiler pressure. These curves could be calculated but the process would be an involved one, so in practice they are obtained by direct calibration

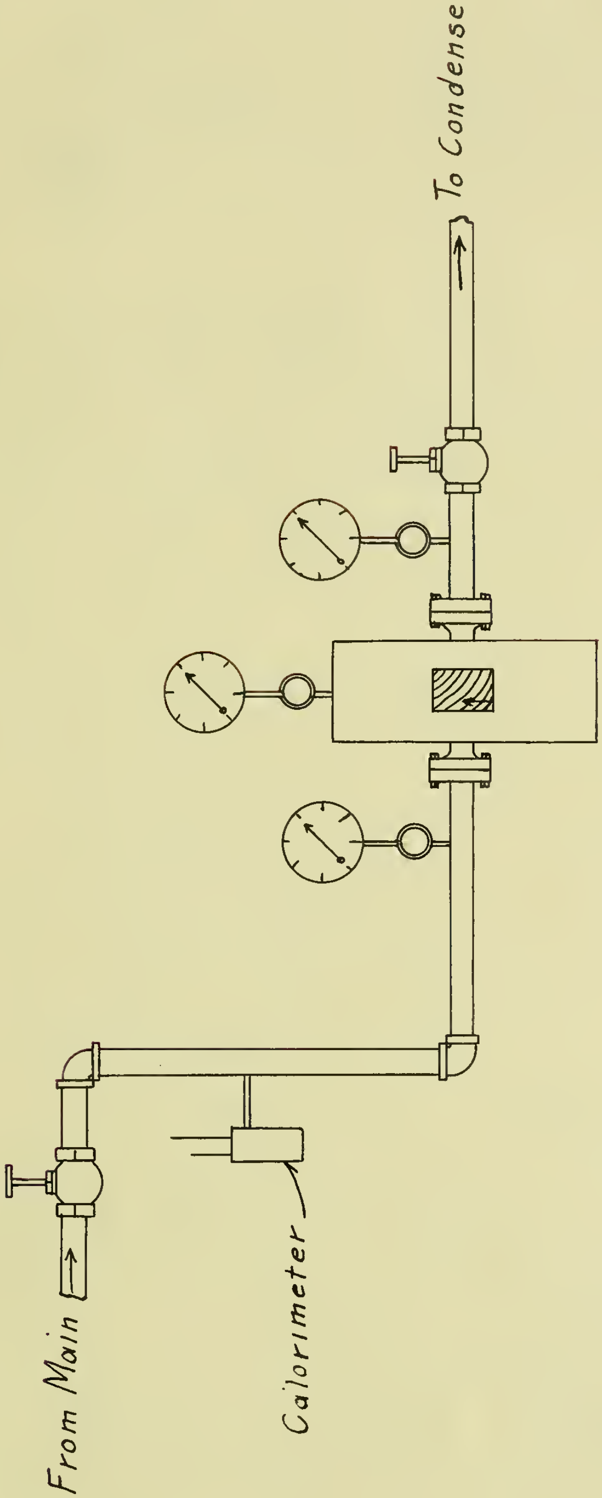
II Object of Tests.

In performing the tests on the meter the main object in view was the determination of the accuracy and reliability of the meter, and to plot curves, which in connection with the meter would enable the observer to obtain the true horse-power from the meter reading.

III Method of Procedure

Arrangement of Apparatus

The general arrangement of the apparatus is shown in the sketch on page 9. The meter used was flanged for a 2" pipe and rated at 100 H.P. between the limits 60 and 120 pounds pressure. It was connected in between the steam main and condenser by a 2" pipe. By means of valves A, and B, both the amount of steam



ARRANGEMENT OF APPARATUS

passing through and the pressure at the meter could be regulated at the will of the operator. It will be seen that the apparatus was so arranged as to allow the calorimeter to be used in a vertical pipe. The condenser was a Wheeler condenser rated at 75 H.P.

Method of Conducting the Tests.

Before making the tests all of the instruments to be used were carefully calibrated. During the tests records were kept of the following items:–

1. Time.
2. Calorimeter temperatures.
3 Pressures.
    1 At meter.
    2 Before meter.
    3 After meter.
4 Meter reading
5 Total weight of water condensed.

The readings were taken every five minutes. Each test extended over a period of two hours, during which time, both the amount of water passing through the meter and and the pressure were kept as nearly constant as possible. The aim was to obtain a series of points corresponding

to full, three-fourths, one-half, and one fourth the rated capacity of the meter at the maximum, minimum, and one intermediate pressure. It was found, however, that owing to the fact that the condenser was too small to condense all of the steam, it was impossible to run at the full rated load of 100 H.P.

IV Results

Methods of Calculation.

As the meter was calibrated to read directly in horse-power, the weight of water passing through it had to be reduced to the same units. As the valve in the meter is so arranged that slugs of water passing through can only strike it in a radial direction, and perpendicular to its line of motion, the lift cannot be effected by the impulse of these slugs passing through at the high steam velocities. Therefore, the only error caused by moisture in the steam is due to the fact that nothing but the volume of steam passing through is measured and recorded, while the moisture gets through without being recorded. This moisture must be subtracted from the total weight of of water on the scales. In finding the moisture a throttling calorimeter was used. The

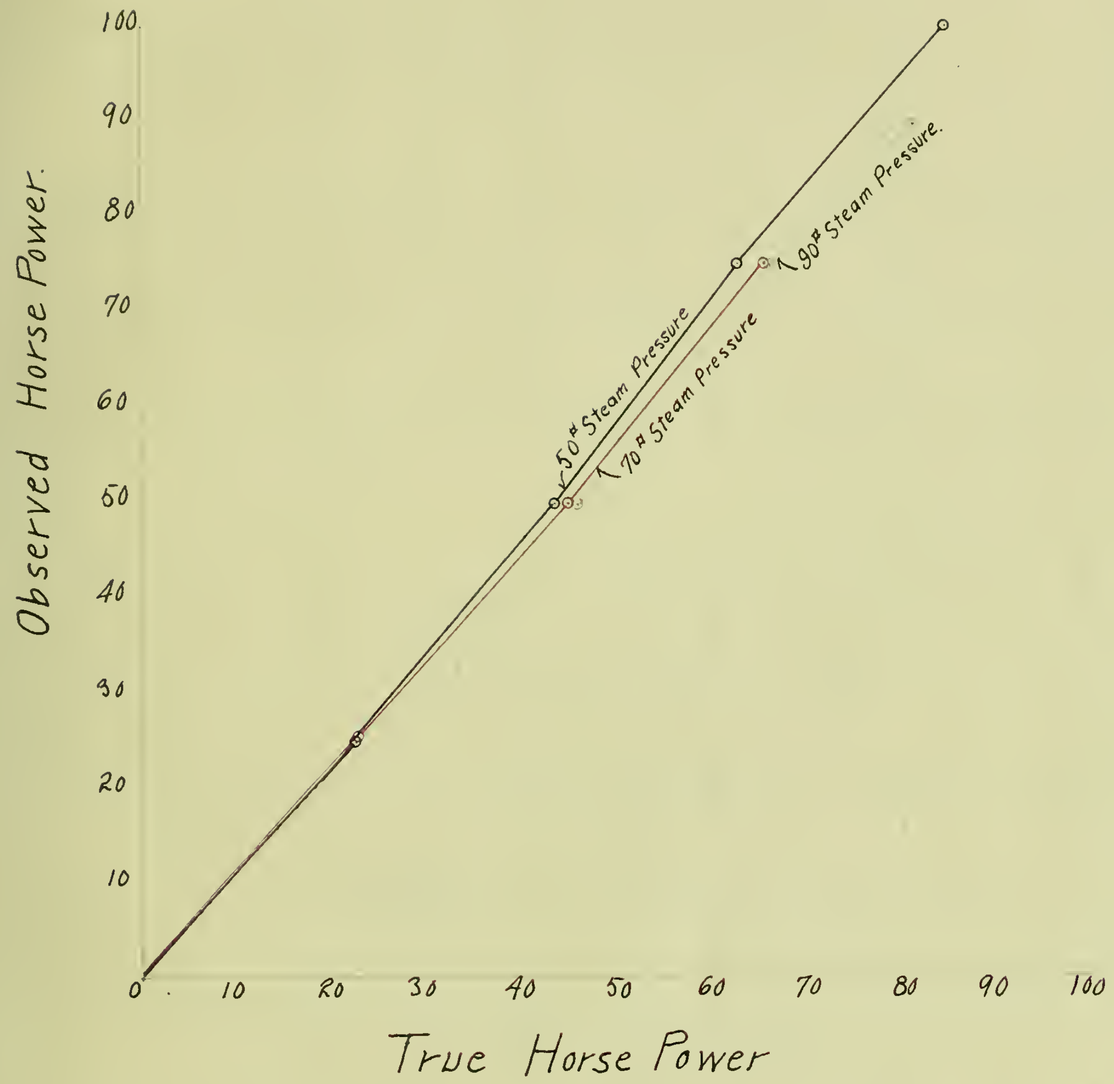
results were then calculated from the formula:—

$X = \frac{\lambda_1 + .48(T_1 - T_2) - q_2}{r_2}$ in which X = quality of the steam, λ_1 = Total heat in steam at atmospheric pressure, .48 = specific heat of superheated steam, T_1 = temperature in low pressure side of calorimeter, T_2 = temperature of steam at atmospheric pressure, q_2 = heat of the liquid at boiler pressure, and r_2 = latent heat of steam at boiler pressure. The water corrected for moisture would then be:- $W' = Wx$. Since a horse-power is defined as 30 lbs. of water from 100°F at 70 lbs gage, a correction was also necessary due to the fact that the steam used was at a different pressure from 70 lbs. Since in the definition of horse-power the steam was taken from feed water at 100°F, while the steam used was taken from the main and could not be referred to feed water, a standard of reference had to be adopted in order to compare the two. The total heat above 100°F was taken in both cases. Letting λ_1 = Total heat above 32°F in steam at given pressure, λ_2 = total heat above 32°F in steam at 70# pressure, and q_2 = heat of the liquid at 100°F. It may now be seen that $\lambda_1 - q_2$ = the total heat above feed water at 100° in the steam at the given pressure, while the $\lambda_2 - q_2$ is the total heat in the steam above feed water at 100°F at 70# pressure.

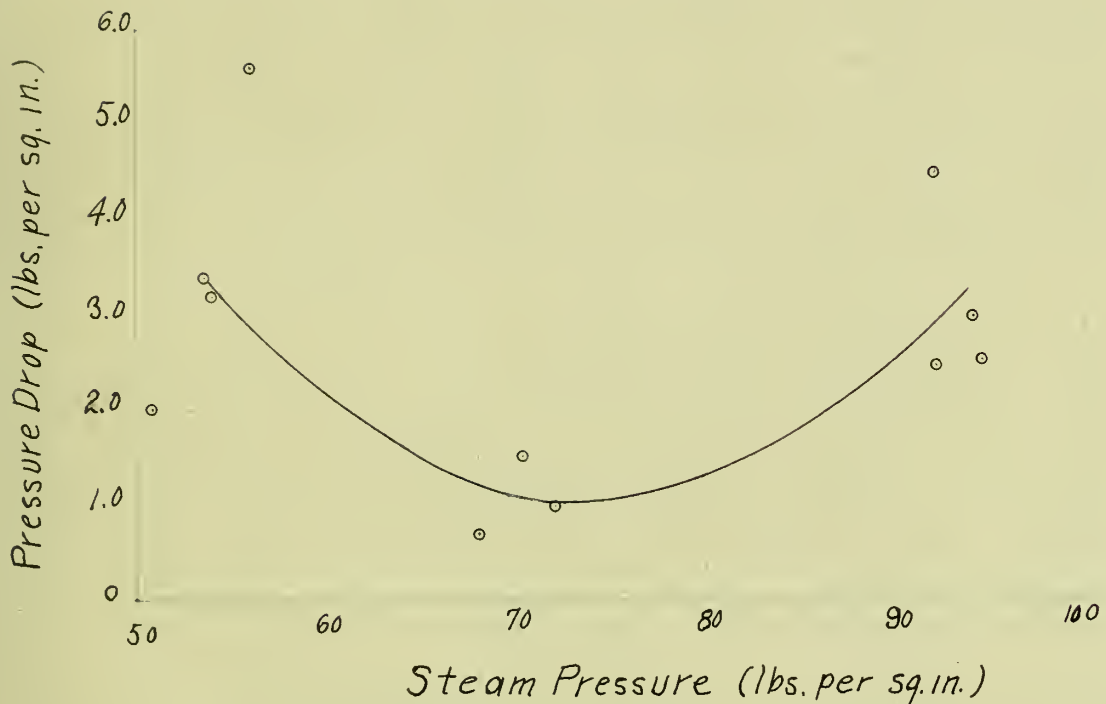
A factor may now be found by taking the ratio of these two, or $F = \frac{\lambda_1 - q_2}{\lambda_2 - q_2}$. The final weight of water would then be given by $W'' = FW'$ and the horse-power would be: $H.P. = \frac{W''}{30}$, in which W'' = the final corrected weight of water per hour.

RESULTS OF TESTS ON SARGENT STEAM METER

Test No.	Pressures			Pressure Drop	Calorimeter Temperature		Moisture	Water lbs. per hr.		Horse-Power		Error
	Before	At	After		High Pressure	Low Pressure		Actual	Corrected	True	Meter Reading	
1	56.0	50.4	50.4	5.6	332.6	261.6	1.50	2572	2530	84.5	100.2	15.7
2	54.4	51.2	51.2	3.2	335.4	263.5	1.50	1908	1880	62.7	75.1	12.4
3	53.6	50.2	50.2	3.4	343.8	268.7	1.50	1311	1292	43.1	50.0	6.9
4	50.8	48.8	48.8	2.8	334.8	263.0	1.50	714	704	22.4	24.9	2.5
5	70.3	68.8	68.8	1.5	344.0	269.0	1.50	1989	1960	65.3	75.2	9.9
6	68.1	67.4	67.4	0.7	314.4	248.2	1.60	1369	1348	44.9	50.5	5.6
7	72.0	71.0	71.0	1.0	333.0	263.0	1.40	717	708	22.6	25.2	2.6
8	94.0	91.0	91.0	3.0	340.0	274.5	1.00	2454	2430	81.0	90.0	9.0
9	92.0	87.5	87.5	4.5	338.0	274.0	1.00	2015	1990	66.3	75.0	8.7
10	94.6	92.0	92.0	2.6	339.0	266.0	1.60	1392	1371	45.8	50.0	4.2
11	92.5	90.0	90.0	2.5	348.0	282.0	0.99	713	705	22.5	25.0	2.5



Calibration Curves
for
100 H.P. Sargent Steam Meter.



Pressure Drop Curve
for
100 H.P. Sargent Steam Meter.

V Conclusions.

Reference to the curves and data will show that the meter was about 15% off in the horse-power readings. This is probably due to the fact that the Bourdon spring had become weakened in some manner, so that while the rated pressure range was 60 to 120 pounds the real range was 35 to 90 pounds. The error produced was very large up in the 100 H.P. low pressure region, and comparatively small in the 25 H.P. high pressure region. Referring to the sketch on page 4, it may be seen that the lines on the dial are very nearly vertical in the former region and nearly horizontal in the latter. An error in the horizontal travel of the pointer, therefore, would produce the same character of error as the results show, so the trouble can be entirely ascribed to this weakening of the spring. It will also be seen that the difference in initial and final pressure is much greater in readings No 1. and No. 9, but the reason for it does not seem evident. Barring the trouble with the spring the meter was very satisfactory, as it read steady, and was sensitive to variations in the steam supply. Placed in the steam line it would give the consumer a very true index of the amount of steam being used, and would eliminate

the trouble and expense connected with tests performed for this purpose.